

# Targeting by Transnational Terrorist Groups

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## Abstract

Many successful terrorist groups operate across international borders where different countries host different stages of terrorist operations. Often the recruits for the group come from one country or countries, while the targets of the operations are in another. Stopping such attacks is difficult because intervention in any region or route might merely shift the terrorists elsewhere. Here we propose a model of transnational terrorism based on the theory of activity networks. The model represents attacks on different countries as paths in a network. The group is assumed to prefer paths of lowest cost (or risk) and maximal yield from attacks. The parameters of the model are computed for the Islamist-Salafi terrorist movement based on open source data and then used for estimation of risks of future attacks. The central finding is that the USA has an enduring appeal as a target, due to lack of other nations of matching geopolitical weight or openness. It is also shown that countries in Africa and Asia that have been overlooked as terrorist bases may become highly significant threats in the future. The model quantifies the dilemmas facing countries in the effort to cut such networks, and points to a limitation of deterrence against transnational terrorists.

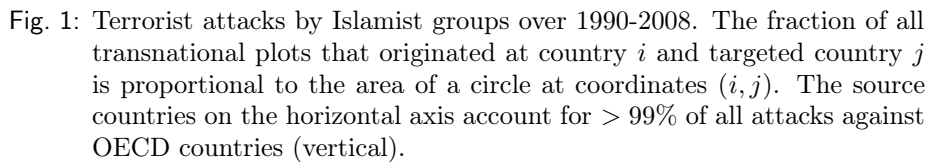
Keywords: terrorism, transnational terrorist networks, activity networks, network interdiction, rational choice theory, LA-UR 10-05689

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## 1 Introduction

Despite vast investments in counter-terrorism, victory in the global war on terror remains elusive. In part this is because terrorist groups are highly adaptive in their tactics and strategy. When airport scanners were installed to detect weapons and explosives, terrorists switched to explosives that cannot be detected using the scanners and to other modes of attack [21, 8]. When it became harder to reach US soil or attack US embassies groups shifted to attacks against other countries or less fortified installations [7, 37]. Like international businesses, globalized terrorist groups are vast international enterprises that tap into the most successful business practices and cost-efficient solutions [2]. If a country erects high barriers to entry or develops an effective domestic counter-terrorism response then terrorists switch their targeting to a safer and more accessible

Adaptability makes risk estimation challenging. One possible basis for risk assessment is extrapolation of historical data, such as the ITERATE dataset of transnational attacks [27]. Fig. 1 shows all ITERATE attacks carried out by Islamist groups on OECD countries in which the national origins of the attackers and the target country are known. Many of the incidents in the matrix are due ethno-nationalist conflicts, such the GIA attacks in France or due to attacks by home-grown cells inspired by Salafis. While a substantial fraction of attacks were against the US, many attacks also targeted France, the UK and other countries.



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1. several regions will become large new sources of transnational terrorism (sec. 4),

2. the US will rise as the terrorists' preferred attack destination (sec. 4),
3. successes in stopping foreign-based plots against the US will increase the threat to other countries (subsec. 4.1), and
4. deterrence will be hard to achieve (subsec. 4.2).

The model is based on an activity network for stages of terrorist attacks. The network represents decisions required for terrorist operations on the global scale, such as which country to attack. No distinction is made between “transnational” and “international” terrorism, both referring to terrorist groups that operate using foreign bases, support or inspiration. This coarsened scale of analysis exposes the strategic picture and can guide counter-terrorism decision making at the national and international levels. It also quantifies a kind of unintended effect from counter-terrorism measures known as “transboundary externality” [30, 31]: the redirection of terrorists from one country to another, because the latter is less protected.

To the author's knowledge, this is the first model of its kind in the open literature. Previous work considered target selection by terrorists but where targets are implicitly within a single country so the costs of bringing the attackers and their weapons to their target are negligible (see e.g. [3]). In contrast, for transnational terrorism security measures and international logistics play a central role in attack planning [16, Ch.3]. Other work considered the structure of the terrorist networks at the level of individual operatives or functions, rather than as a global network (cf. [10, 23, 5, 13, 38].)

It is sometimes argued that such economic models of terrorism are unreliable because terrorism is an irrational behavior by fanatics. However, the preponderance of evidence supports the alternative view - the rational choice theory (RCT) [34]. RCT claims that terrorist groups and leaders are rational agents capable of strategic decision-making. Their decisions are expressions of “instrumental rationality”, that is, consistent with their values and objectives [20]. The sophistication and technological adaptability of terrorists, such as in developing triggers for explosives, is strong evidence for their intelligence [18, 15]. More evidence for RCT comes from studies of target selection [31]. Those consistently find evidence for a substitution effect - as governments improve protection to certain targets, terrorists substitute them with less protected targets [1, 6, 15]. Indeed, the defining feature of terrorism - the use of violence against civilians rather than against military targets - is a strategic substitution effect because the latter are harder targets. Another line of evidence for rationality comes from analyzing the internal dynamics of terrorist groups. Rather like non-violent organizations, they perform cost-benefit analyses, employ financial controls and run financial audits [33, 32].

## 2 A Model of Transnational Terrorism

We now describe a model of a transnational terrorist groups. Such groups are characterized by their global aims, as opposed to regional conflicts; they recruit

and attack throughout the world. Islamic fundamentalist groups will serve as the central application of this model. These include al-Qaida, Hezbollah but also possibly extremist groups not currently thought to be violent, such as Hizb-ut-Tahrir. Rather than considering specific groups and limiting to their current bases of operation, this study will consider every region of the world that currently or may in the future host violent Islamic groups. We focus on those groups because they are probably the most potent present-day transnational terrorist threat. The model could also evaluate other violent transnational ideologies if we re-estimate its parameters.

## 2.1 Operations Submodel

Suppose a transnational group controls a cell in a country, and must decide where to dispatch this cell (the cell might also be self-mobilizing, in which case it must solve its own targeting problem.) The three options are (1) do a domestic attack, (2) send the cell to attack another country, and (3) do nothing. Option (1) entails certain risks and costs for collecting intelligence and preparing weapons. Dispatching the cell into another country, (2), incurs the additional cost and risk of interception due to security barriers, such as visas, intelligence collection in a foreign environment, and cultural difficulties. However, the other country might have more favorable security environment or offer better targets - more significant or less protected. Option (3) - abandon the attack and hide - has little or no risk or accounting cost and preserves the cell for future operations.

Any rational decision maker must weight the costs and benefits and take the action offering the greatest net benefit. Surely then terrorists would also do such analysis, weighing at least the most obvious target choices and travel routes. A simple way of representing this is with an activity network, where nodes represent different stages of terrorist operations at different countries, and edges show the cost and risk involved in each stage (Fig. 2). In Fig. 2, the columns correspond to the countries, including the country of origin, while the rows correspond to the postures of the cells: the stages of the plots.

The network represents the options of the rational decision maker as directed paths - chains of nodes and directed edges that start in the source country node and lead to either the “attack” node or the “abandon/hide” node. If complete information is available about the costs and benefits of each option, then the rational decision is to select the path with the highest utility, that is the path with highest net benefit (benefit minus cost.) For any path  $p$ , the cost  $c(p)$  is found by adding the weights on the edges (tasks) constituting the path.

The edge weights of this network could represent resources like money or materiel that are consumed and produced by terrorist operations. The network could also be used to perform a probabilistic risk assessment (PRA): to evaluate the gains from possible operations and the probabilities of successfully completing intermediate stages in the operations. Such a PRA is what we will do. In other words we will take the perspective of the terrorists: determine what they

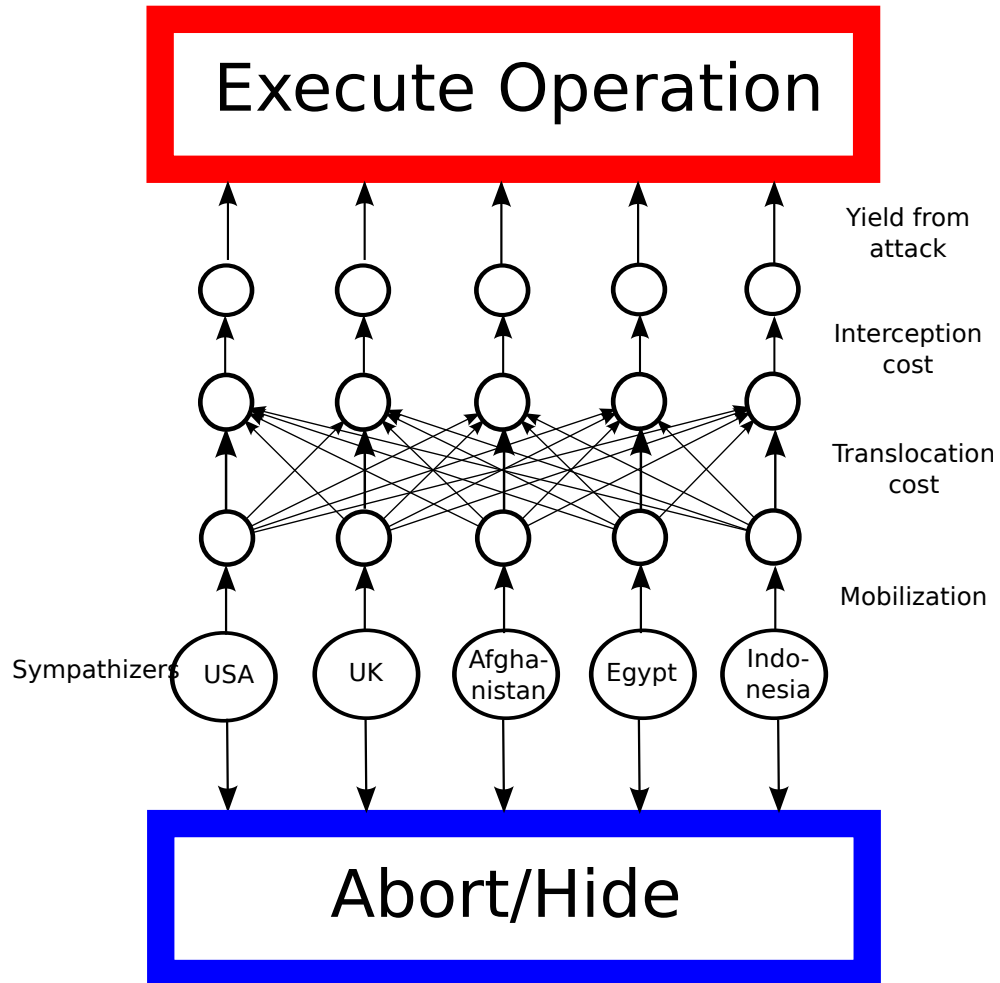


Fig. 2: Illustration of the model for 5 countries. The vertical direction represents countries while the horizontal represents different stages in execution of plots. Domestic attack plans correspond to motion upwards, while transnational attacks also make a diagonal transition. The full model includes many more countries.

want and what they fear in order to anticipate how they will act<sup>1</sup>.

It is an open question whether terrorist groups can or will use such an algebraic method to analyze their operations. However, given their sophistication they may well come to the same decisions using other means or through operational experience. Of course they might also intentionally avoid the most probable attacks to achieve surprise, but only at a cost (and models could also be constructed to anticipate that too.)

Consider now the following specific model for transnational terrorist attacks, Fig. 2. A cell that was mobilized at country  $i$  experiences (1) the translocation cost/risk,  $T_{ij}$ , representing the barriers for moving from country  $i$  to country  $j$ ; (2) the risk of interception at country  $j$ ,  $I_j$ ; and (3) the yield  $Y_j$  from attacks at country  $j$ . Yield reflects the gain to the terrorists from a successful attack, and so has the opposite sign from cost. A domestic attack at country  $i$  has cost  $c(p) = T_{ii} + I_i + Y_i$  while a transnational attack has cost  $c(p) = T_{ij} + I_j + Y_j$  ( $i \neq j$ ). Because negative edge weights are costs in the sum that represent risks, the words “cost” and “risk” will be used interchangeably. Sometimes attackers reach country  $j$  through one or several intermediate countries (exploiting e.g. the Schengen treaty), a possibility we ignore for simplicity. From the counterterrorism point of view, the likelihood of a particular plot depends also on the supply of plots originating at each country. Therefore, we will estimate for each country  $i$  the number of cells that originate there,  $S_i$ . If the group decides to abandon, its path has cost  $c(p) = A$ . The value of  $A$  may be a negative, representing the preservation of the cell, or positive, if the cell cannot be reactivated.

It is possible to include additional costs like cost of recruitment or training in the model but this will be left for future studies because the data is hard to estimate. Here it was assumed that the costs are negligible and indeed many cells involved in recent attacks recruited themselves and trained with information obtained from websites. Another possible extension is attacking country  $j$  through its foreign representatives: embassies, officials and even tourists. Such attacks represent a different type of attack path and could be easily added, albeit by adding more hard-to-estimate parameters to the model. Similarly, one may consider attack on modes of international transit such as airplanes and ships.

The model’s parameters can be estimated from open source information with a modest degree of confidence (see section 3). Briefly, transit costs were estimated from data on global migration, the risk of interception from national

<sup>1</sup> Here is how PRA is represented by networks. Suppose in a multi-stage terrorist operation  $r_s$  is the probability of success at stage  $s$  (out of  $k$  stages in total) conditional on success at every previous stage. Suppose the gain from a successful operation is  $G$  ( $\geq 1$ ). Then the expected gain from the operation is  $E = r_1 r_2 \dots r_k G$ . Let us now relate  $r_s$  values to costs ( $c_s \geq 0$ ) using exponentiation:  $r_s = e^{-c_s}$ , and let the gain be a function of yield  $Y$ :  $G = e^{-Y}$ . Thus, an attack has expected gain  $E = \exp[-(c_1 + c_2 + \dots + c_k + Y)]$ . In the network representation of terrorist operations, we can compute the sums in the exponent by adding edge weights along network paths that trace through all the stages. Paths of lower weights translate to attacks of greater expected gain. By comparing such paths we could anticipate which attacks would have the highest expected gain.

expenditure on internal security and attack yields based on the political power of the targeted country, represented by its GDP. The supply of plots is estimated from public opinion surveys measuring support for terrorist attacks and demographic data.

## 2.2 Stochastic Decisions Submodel

If transnational terrorist groups could determine the values of the parameters precisely (the next section discusses this problem), then they should be able to plot the optimal attack from each country  $i$  by considering all possible options and finding the path that minimizes cost:

$$\min_j \left[ \underbrace{T_{ij} + B_j + Y_j}_{c(p_{ij})} \right].$$

However, one of the general difficulties in decision making is uncertainties about costs and risks. Terrorists, like other decision makers should therefore occasionally identify the optimal attack incorrectly. Reliable risk assessment must therefore take into account the possibility that adversaries make mistakes (as well as use unpredictability to achieve surprise - but that is even harder to assess.) Fortunately, suitable stochastic prediction methods have already been developed for activity network models like in Fig. 2. With those methods probabilities can be assigned to different terrorist plans based on the costs of the corresponding paths on the network. We use the model in [14, Ch.3] based on Markov chains. In it the path of least cost is typically assigned the highest probability but other paths have non-zero probabilities, and these probabilities can be quite high (for details see Appendix, sec. B).<sup>2</sup>

From this Markov chain model it is possible to compute the number of times any particular country (represented by its attack node) would be targeted as well as to compute the changes in targeting due to various defensive actions, which are represented as increases in edge weights. It is also possible to determine whether defensive actions would materially increase the costs for the adversaries or merely lead them to change targets.

<sup>2</sup> One of the advantages of the stochastic model is that it can interpolate between the two extremes of complete ignorance and perfect information using a single parameter  $\lambda$  ( $\geq 0$ ) that describes the amount of information available to the adversaries. For a given level of information, the probability that a path  $p$  would be selected is proportional to  $\exp(-\lambda c(p))$ . When  $\lambda$  is very large the path of least cost has a much higher probability than any of the alternatives, while  $\lambda$  close to 0 assigns all paths approximately the same probability. We set  $\lambda = 0.1$  in the following but its value has a smooth effect on the predicted plots (i.e. the sensitivity is low). A value of 0.1 means that if the terrorist group learns of a increase in path cost by 10 units, its probability of taking the path will decrease by a multiplicative factor of  $\approx 2.72$ . The effect depends on the original path probability: it is not as great a decrease when the original probability is high.

### 3 Estimation of Parameters

The model contains several sets of inputs: (1) the supply of plots at country  $i$ ,  $S_i$ ; (2) barriers for moving from country  $i$  to country  $j$   $T_{ij}$ ; (3) risk of interception at country  $j$ ,  $I_j$ ; and (4) the yield from attacks at country  $j$ ,  $Y_j$ . The yield of abandoning,  $A$  will be set to  $\infty$  (no abandoned plots) and its effect will be analyzed separately. Because (1)-(4) contain security-related information that is also difficult to measure, the information is not published. Luckily, one can derive estimates from publicly-available demographic and economic data. Readers wishing to see the final results of estimates should skip to tables 1, 3 and 2 of the Appendix and ignore the rest of this section.

In building the estimates, it will be assumed for simplicity that each stage of terrorist operations carries about the same amount of risk. Namely, that the medians of  $T_{ij}$  ( $i \neq j$ ) and of  $I_j$  both equal 1. Of course, some plots will be much less risky than others because both  $T_{ij}$  and  $I_j$  have considerable variability. The yield from attacks is also normalized relative to the median. Transformations of this kind on costs and yields are unavoidable if we wish to remove the effect of units, but they do reduce the reliability of the model. However, the core findings of the model regarding certain countries agree well with intuition, as will be seen.

#### 3.1 Estimating the Supply of Plots, $S_i$

To assess the threat from the greater violent Islamic movement it is not sufficient to consider the support for a particular group like al-Qaida. Even if we assumed that al-Qaida has no support in certain countries, other groups might mobilize supporters there. Another concern is self-mobilization: modern terrorist groups sometimes avoid active recruitment and instead provide inspiration and guidance while relying on self-radicalization to provide them with foot soldiers [29].

A comprehensive picture on possible plots can be obtained from surveys. Over the last decade most recently in 2009 the Pew charitable trusts run several global attitude surveys which among others, asked Muslims about their support for suicide bombings [36]. In each of the surveyed countries respondents were asked to state whether suicide bombings is “never justified” ( $\sigma^n$ ), “rarely justified” ( $\sigma^r$ ), “sometimes justified” ( $\sigma^s$ ), and “often justified” ( $\sigma^o$ ). These are given as fractions of the respondents. For some countries no data was available, so the quantities were extrapolated from countries in the same geographic region (e.g. Middle East, Americas etc.) Pew also collected data on the Muslim population in 235 different countries and territories ( $J_i$ ) [24] (of course the overwhelming majority of Muslim everywhere are opposed to terrorism in the name of their religion). The supply of violent plots can be estimated by taking the population and multiplying by the weighted fraction of respondents professing support for violence (the weights are  $s_r, s_s, s_o$ ). One must also take into account that only a small fraction of those who profess radical ideology would actually be involved



in a plot and that several people are involved in each plot (a factor  $Q$ ):

$$S_i := Q \cdot J_i \cdot (s_r \sigma^r + s_s \sigma^s + s_o \sigma^o) .$$

The support weights were set by default based on the assumption that every increase in professed support leads to an increase by a factor of 2 in the resources available to terrorist groups:  $(s_r, s_s, s_o) = (0.25, 0.50, 1.00)$ . Appendix A explores the sensitivity of supply  $S_i$  to this assumption through two alternatives: most of the tangible support come from the narrow but committed minority,  $(s_r, s_s, s_o) = (0.1, 0.2, 1.0)$ , and a situation where even the least-committed supporters materially boost the terrorists,  $(s_r, s_s, s_o) = (0.33, 0.66, 1.00)$ . Notes that the weights effect only the relative importance of regions as sources of terrorism, not the targets of plots originating in a given region.

The factor  $Q$  is dependent on social and tactical issues, and hence should not vary much across countries. Because  $Q$  enters as a multiplicative term at all source countries, its value has no bearing on the relative risk estimates. Nevertheless, it could be crudely estimated as follows. In 2006 the head of the British Security Service (MI5) reported that: "... my officers and the police are working to contend with some 200 groupings or networks, totaling over 1600 identified individuals (and there will be many we don't know) who are actively engaged in plotting, or facilitating, terrorist acts here and overseas" [25]. Furthermore "over 100,000 of our citizens consider that the July 2005 attacks in London were justified." This implies active participation at a rate of at least 1.6% and 8 people per plot ( $Q = 0.002$ ).

### 3.2 Estimating the Barriers for Moving from Country $i$ to Country $j$ , $T_{ij}$

Barriers to transnational attacks include both deliberate barriers such as screening and intelligence, and unofficial barriers such as differences in language and culture. Official barriers depend on factors such as the intelligence available on targets in the destination country, the cooperation the targeted country received from both the country of departure and the transport agent (e.g. airline). None of those figures are publicly available but a proxy measure can be found, as follows. Transnational terrorists often use tourism, education or immigration as cover to obtain travel documents and permits. Indeed, travel in all of those categories became more difficult across the developed world as a result of the security measures introduced after the 9/11 attacks. Migration patterns thus provide an estimate of official barriers. Unofficial barriers to migration are likewise similar to the unofficial barriers to terrorism, including differences in language, culture, ethnicity and others. Therefore, the foreign-born migrant population, suitably normalized, could be used as a proxy of transnational freedom of travel. Migration into most OECD countries is documented by the OECD [28].

It is to be expected that the number of migrants would be positively correlated with the population of the countries and negatively correlated with distance. This is known as a "gravity law" model. Many national and international relationships such as trade flows are well-approximated by gravity laws [9, 19],

named for their similarity to Newton's law for the force of gravity. Therefore an estimate for the number of migrants between country  $i$  and country  $j$  is the product of their populations (data: UN) divided by their distance squared (data: CEPII [26]):  $\frac{p_i p_j}{d_{ij}^2}$ . When the actual number of migrants,  $m_{ij}$ , falls below this estimate, that may indicate heightened official or unofficial barriers. Thus we define the raw transnational terrorism barrier between countries  $i$  and  $j$  as:

$$\widehat{T}_{ij} := \frac{p_i p_j}{d_{ij}^2} / m_{ij}.$$

The data must now be standardized, for several reasons: (1) the barrier data should be comparable with other costs considered by the terrorists (and in the model) by removing the effects of units for population and distance; and (2) since the barrier is a cost and risk, it must be represented by positive number in the activity network. Therefore, the quantity  $T_{ij}$  was computed from  $\widehat{T}_{ij}$  by determining the minimum ( $\text{Min}\widehat{T}$ ) and median ( $\text{Med}\widehat{T}$ ). Because of (2)  $\text{Min}\widehat{T}$  is subtracted from  $\widehat{T}_{ij}$ , and for (1) the quantity is divided by the median of the shifted values:

$$T_{ij} = (\widehat{T}_{ij} - \text{Min}\widehat{T}) / (\text{Med}\widehat{T} - \text{Min}\widehat{T}).$$

The resulting values have a median of 1.0. The more standard procedure of first removing the average and dividing by the standard deviation was rejected because the distribution is visibly non-Gaussian with large positive outliers (hence a skewed mean and large variance). Domestic operations will be assumed to have negligible barriers ( $T_{ii} = 0$  for all countries  $i$ ). The OECD data lacks information about migration to non-OECD countries. Therefore set  $T_{ij} = \infty$  in all such cases (effectively blocking such paths).

While the OECD includes some of the most geopolitically-important nations of the planet, obtaining data on translocation costs to non-OECD countries would be valuable for two reasons. First, only with such data can we estimate the risk of terrorism to those nations (such as the July 11 bombings in Kampala), and second to estimate the effect of counter-terrorism policies in the OECD on terrorism in other countries. Indeed, in the ITERATE database of terrorist incidents [27], attacks on OECD countries that can be traced to Islamist groups account for only 22% of all Islamist attacks.

### 3.3 Estimating the Risk of Interception at Country $j$ , $I_j$

The risk of interception can be estimated from OECD data on expenditure on public order and safety as percentage of GDP. The relevant figure is the fraction of GDP rather than the raw figure because the number of valuable targets is related to the size of the economy, so the fractional figure indicates the

level of security vulnerable sites can receive. The GDP also correlates with the population size (in rich countries) and thus to the amount of police resources available per person. The extreme case of totalitarian police states is suggestive:

in such countries internal security expenditures are disproportionately large relative to the GDP, and indeed terrorists have a lot of difficulties operating there [17]. This estimate of course neglects the efficiency of internal security force - a factor that is hard to estimate.

The internal security data is transformed almost exactly like the barrier data and for the same reasons: start with figures for internal security expenditure as a fraction of GDP for country  $j$ ,  $SEC_j$  then compute the minimum ( $MinSEC$  =  $\min_j SEC_j$ ) and median ( $MedSEC$ ), and then normalize:

$$I_j = (SEC_j - MinSEC) / (MedSEC - MinSEC) .$$

Generally speaking, we find that there is not much variation in the risk of interception in different countries (raw data is in the Appendix, sec. A), as compared to variation in factors such as yield, discussed next. This suggests that interception risk plays a minor role in target choice.

### 3.4 Estimating the Yield from Attacks at Country $j$ , $Y_j$

Transnational terrorist attacks attempt to influence policies. For example, one of al-Qaida's original objectives was to compel the withdrawal of US forces from Arabia, while Hezbollah forced France and the US to withdraw their peacekeepers from Lebanon in the 1980s. The precise value of targets shifts with time and the political situation, but typically larger richer countries make for more powerful players in the international arena, and hence more important targets. Moreover, their homelands carry more targets of symbolic, political and economic significance. The economic damage from the loss of life and physical assets is also higher in richer countries because they tend to have higher productivity for labor and capital. Thus, it is expected that transnational terrorists would seek to attack larger richer countries. The weight of a country can be estimated from its dollar GDP figures at current exchange rates (source: UN data).

Timing or political dynamics does play a role in transnational terrorism but its importance might be overestimated. For example, the Madrid 2004/03/11 train bombings are often viewed as intending to pressure the Spanish government to withdraw its forces from Iraq, and they were timed with the Spanish elections. But surely an important factor was Spain's geopolitical weight (GDP is ranked 12th in the world) and its large contribution to the 2003 invasion. Otherwise al-Qaida could have just as well pressured smaller countries such as El Salvador and Mongolia to withdraw their contributions to the invasion.

Here is how the yield  $Y_j$  was computed from the GDP figures. Recall that costs (barriers, internal security) are all positive, so yields must be negative. Let the minimum GDP be  $MinGDP$ , and the median  $MedGDP$ . The following formula produces negative values with a standardized median:

$$Y_j = (MinGDP - GDP_j) / (MedGDP - MinGDP) .$$

The resulting values have a median of  $-1.0$ .

## 4 Predictions

One way of representing the solution of the model is through an attack matrix, the counterpart of the historical data matrix in Fig. 1.) The model predicts (Fig. 3) that the United States would attract the bulk of transnational terrorism - all other countries are almost free of terrorism (white squares). The reason the United States is such a magnet is because of its vast geopolitical weight and relatively open borders.

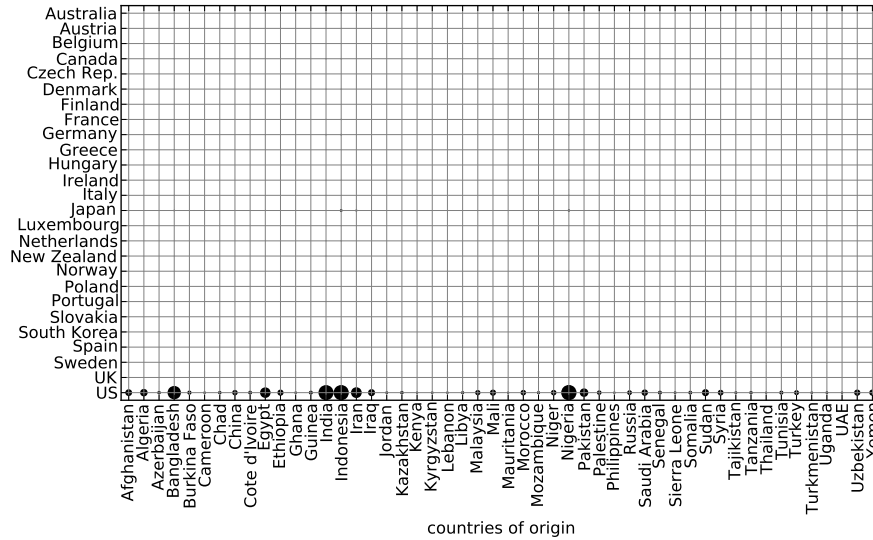


Fig. 3: Predicted attack risk matrix. The area of a circle at coordinates  $(i, j)$  is proportional to the number of plots from  $i$  to  $j$ . The bottom row indicates that the vast majority of plots target the US.

Examination of the sources for attacks exposes a number of risks. There is a considerable terrorist threat from Bangladesh, India, Indonesia and Nigeria. They combine a large population and relatively high support for terrorism. It is notable that the 2009 Christmas bomber was Nigerian - one of the first attacks on OECD from that country.

The high burden of attacks borne by the US is directly related to the rational choice model: if there is a big prize to be won by attacking the US, no rational terrorist would attack other countries. The reasons why non-US attacks do occur (cf. Fig. 1) include: (1) some terrorist groups such as ethno-nationalist groups see as their enemy a particular country and lack a global strategy; (2) global Salafi groups have not yet expanded their recruitment channels in countries such as Nigeria and Bangladesh, so a large fraction of attacks is still carried out by groups with more narrow agendas; and (3) the US has deployed counter-terrorism measures commensurate with the threat it faces, making the US too

costly to attack.

One implication of this finding concerns US policy. The matrix justifies in principle outlays by the US government towards countering international terrorism as a whole, without regard to its target. Investments in international counter-terrorism measures, such as policing, if effective in reducing the number of plots, are also efficient from the US perspective because the US, being the target of choice, will retain most of the benefits from reducing the terror threat [22]. Unfortunately, many policies previously adopted were ineffective or had perverse effects on international terrorism (the so-called “blowback”) (see e.g. [11, 12].)

#### 4.1 National Fortresses

Consider now several alternative scenarios for the future, motivated by strengthening of counter-terrorism defenses, which may make transnational attacks less feasible. Suppose the US was successful in deterring attacks against itself by greatly increasing the barriers to entering US soil. If so, Fig. 4 shows the likely effect.

The protection of US frontiers will significantly increase the attack risk to most other OECD nations because transnational groups should then switch to more accessible targets. Perhaps surprisingly, Japan, now rarely mentioned as a target will see the largest absolute increase in terrorism. This prediction is due to its international profile, Japan being the second largest country in the OECD on several measures. Japan’s woes will be shared to some extent by most other major OECD countries, who will also see an increase in attacks.

Another possible scenario is where the security forces in each country are able to intercept the majority of external plots against their homelands. In other words, the translocation cost becomes very large ( $T_{ij} = \infty$  for  $i \neq j$ ). In this world, the dominant form of terrorism is home-grown. As Fig. 5 shows, this materially changes the risk matrix. Countries such as the France, with relatively large and relatively radicalized Muslim communities will see much more terrorism.

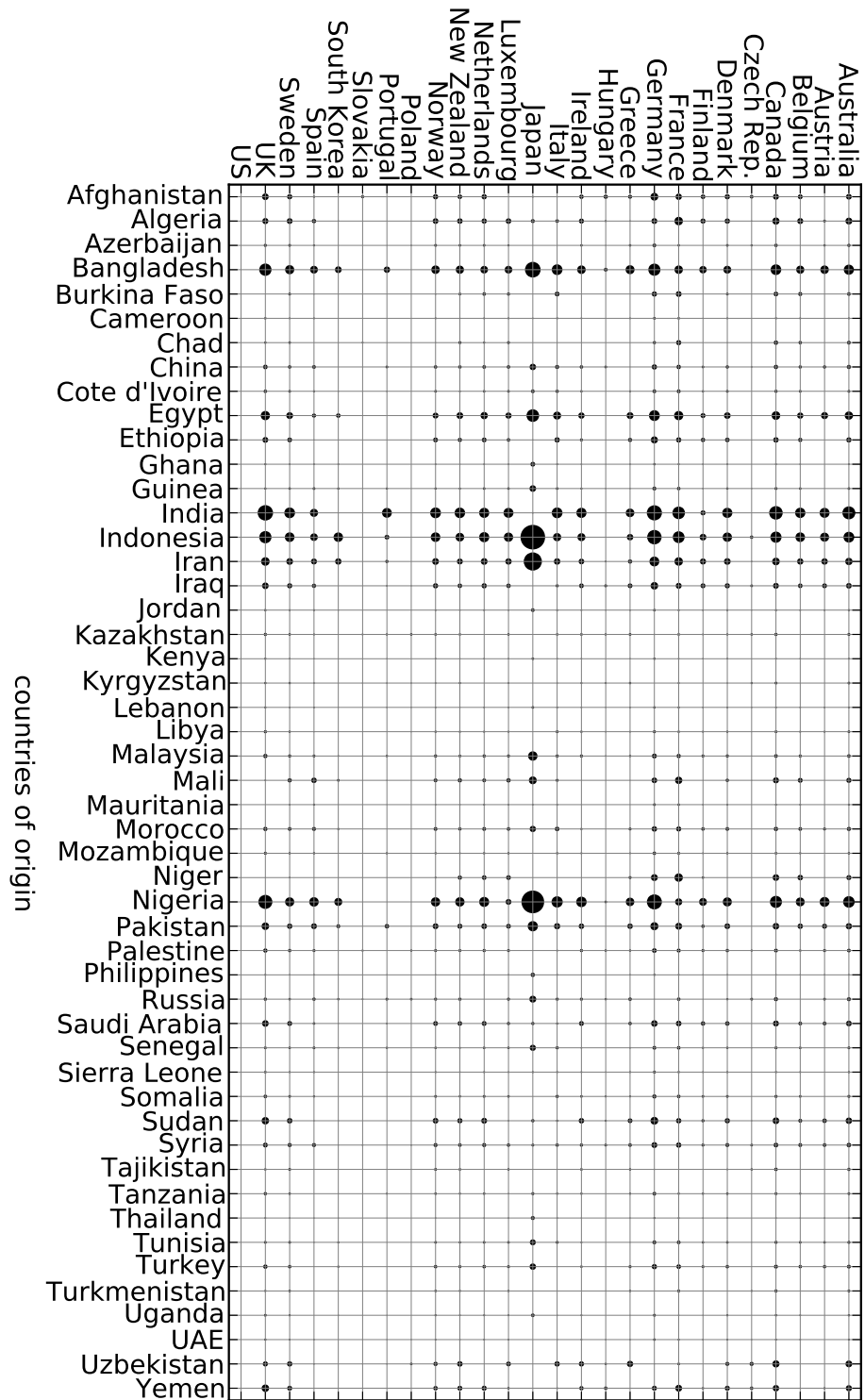
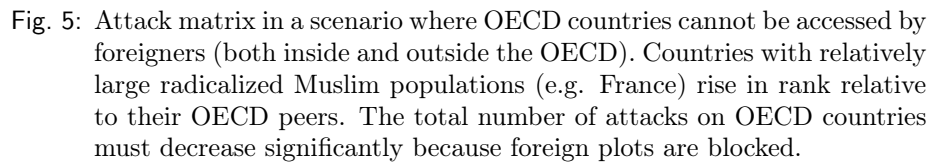


Fig. 4: Attack risk matrix in scenario where US becomes inaccessible to foreign plots. Terrorist plots increase in all other OECD countries.



## 4.2 Deterrence

A number of defensive strategies are founded on deterrence. In terrorism, deterrence may involve convincing would-be groups or cells that operations are too risky or that the entire struggle they wage is hopeless. The model can express such conditions on a global level by varying the parameter  $A$ , the perceived yield from abandoning. Raising this yield is equivalent to raising risks throughout the network. The effect of  $A$  is non-linear, showing a threshold at around  $A = -35$  beyond which attacks decline (Fig. 6.) Unfortunately, the threshold lies quite high, indeed nearer to the yield from attacking the US ( $-54$ ) than

countries such as France ( $-6.8$ ), implying that it would be necessary to create a very large deterrence effect to reduce the number of plots.

If this level of deterrence is somehow achieved, the reduction in attacks will not occur at once in all countries because cells in some countries have lower translocation costs than cells in other countries. As a result, their perceived net benefit and probability of success are higher. Thus plots originating within the developed countries such as the G7 and especially home-grown plots will be the last to experience deterrence because they originate so close to high-value targets.

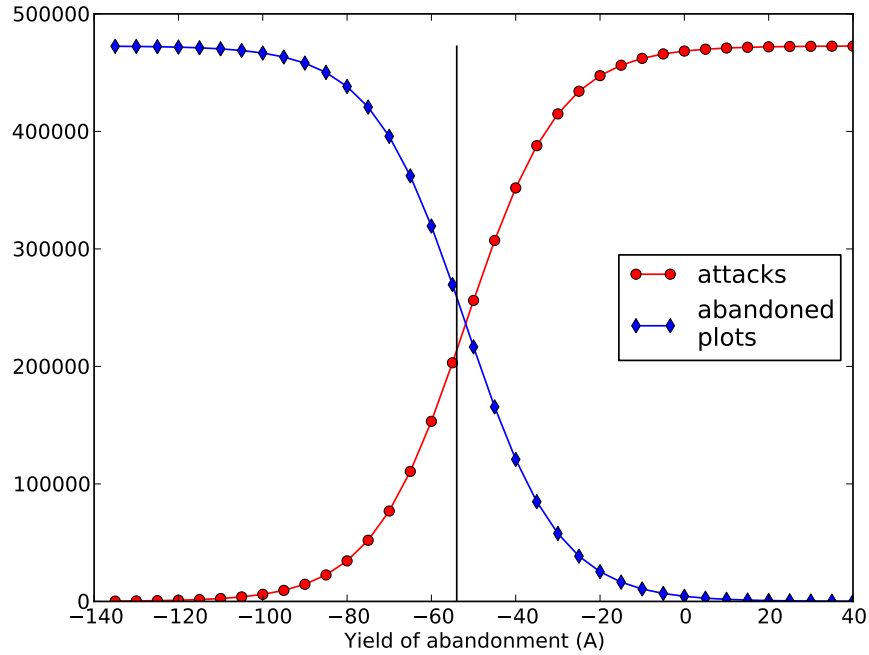


Fig. 6: The number of attacks as a function of the yield from abandoning. Negative values make abandoning more competitive and decrease attacks (left side) while positive values indicate that abandoning is costly and encourage attacks (right side). The vertical black line indicates the yield from attacking the US - the most valuable target. The sigmoid shapes suggest that the effect of deterrence is low until a threshold is reached, but the threshold must be close to the perceived value of attacking the US.



## 5 Discussion

The network model draws attention to differences between our past experience with terrorism and its possible future. Populous regions like Nigeria and Bangladesh are predicted to produce many plots although they have not participated significantly in transnational terrorism yet. If those regions start producing terrorists at a level commensurate with their size and radicalization, the world will see many more attacks. Alternatively, it is possible that those regions have characteristics that hold back violent extremism. If so, future research should identify those characteristics and suggest policies that maintain and encourage them.

The model confirms the significant danger from substitution effects. Perceived successes in reducing the number of attacks against it may be due to a strategic redirection by terrorist groups that increases the risk to other countries. In the scenario where the US deters all attacks by foreign terrorists, many other countries would experience a large increase in threats. To an extent this has already been seen in Europe.

The model introduced above has limitations, some introduced for simplicity, some that are inherent from its foundation as a network model. Perhaps the most significant shortcoming is the assumption that a terrorist group's main resource are its human resources. In practice, attacks also require intelligence gathering, training and materials. Those resources need to be brought together while maintaining motivation and secrecy. Nevertheless, the model captures some of the probabilistic analysis used by transnational groups within the well-developed framework of network theory.

## 6 Conclusions

The paper introduces a model of transnational terrorist groups that represents operations as a global activity network. It is possible to estimate the parameters of the model, and then predict the number of plots directed at OECD target countries from countries throughout the world. The model highlights the exceptionally high risk of attacks against the US. If the US is successful in deterring attacks against itself without reducing the overall supply of terror then most OECD countries would see sharp increases in attacks because of a substitution effect.

The scale of the substitution effect calls for studies into counter-terrorism policies that are designed to anticipate and sterilize it. Fortunately, the problem, termed "network interdiction" has already been studied in the context of other networks [35, 4]. Those mathematical methods can identify where barriers can be erected in the transnational terrorist network to produce an increase in the costs to the terrorists in such a way that they cannot avoid it by shifting their plots to other countries. Therefore it should be possible to develop efficient and game-theoretically robust multi-national defense strategies.

## Acknowledgments

A conversation with Gordon Woo has inspired this work. Matthew Hanson and Vadas Gintautas suggested useful improvements. Part of this work was funded by the Department of Energy at the Los Alamos National Laboratory under contract DE-AC52-06NA25396 through the Laboratory Directed Research and Development program, and by the Defense Threat Reduction Agency grant “Robust Network Interdiction Under Uncertainty”. Released as Los Alamos Unclassified Report 10-05689.

## References

- [1] Charles H. Anderton and John R. Carter, *On rational choice theory and the study of terrorism*, *Defence and Peace Economics* **16** (2005), no. 4, 275–282.
- [2] John Arquilla and David Ronfeld, *Networks and netwars: The future of terror, crime, and militancy*, RAND Corporation, Santa Monica, CA, 2001.
- [3] Vicki M. Bier, Santiago Oliveros, and Larry Samuelson, *Choosing what to protect: Strategic defensive allocation against an unknown attacker*, *Journal of Public Economic Theory* **9** (2007), no. 4, 563–587.
- [4] Gerald G. Brown, W. Matthew Carlyle, Robert C. Harney, Eric M. Skroch, and R. Kevin Wood, *Interdicting a Nuclear-Weapons Project*, *Operations Research* **57** (2009), no. 4, 866–877.
- [5] Steven R. Corman, *Using activity focus networks to pressure terrorist organizations*, *Computational and Mathematical Organization Theory* **12** (2006), 35–49.
- [6] Laura Dugan, Gary Lafree, and Alex R. Piquero, *Testing a rational choice model of airline hijackings*, *Criminology* **43** (2005), no. 4, 1031–1065.
- [7] W. Enders and T. Sandler, *Distribution of transnational terrorism among countries by income classes and geography after 9/11*, Report by the Center for Risk and Economic Analysis of Terrorism Events (CREATE), 2005.
- [8] Walter Enders and Todd Sandler, *What do we know about the substitution effect in transnational terrorism*, *Researching Terrorism: Trends, Achievements, Failures* (A. Silke, ed.), Frank Cass: Ilford, 2004, pp. 119–137.
- [9] Sven Erlander and Neil F. Stewart, *The gravity model in transportation analysis: theory and extensions*, *Topics in transportation*, vol. 3, VSP, 1990.
- [10] A. S. Finbow and B. L. Hartnell, *On designing a network to defend against random attacks of radius two*, *Networks* **19** (1989), no. 7, 771–792.

- [11] Boaz Ganor, *The counter-terrorism puzzle: A guide for decision makers*, Transaction Publishers, Piscataway, NJ, 2005.
- [12] ———, *Terrorist organization typologies and the probability of a boomerang effect*, *Studies in Conflict and Terrorism* **31** (2008), 269–283.
- [13] Alexander Gutfraind, *Constructing networks for cascade resilience*, 2009, <http://arxiv.org/abs/0906.0786>.
- [14] ———, *Mathematical terrorism*, Ph.D. thesis, Cornell University, Ithaca, New York, USA, Aug 2009.
- [15] Matthew A. Hanson, *The economics of roadside bombs*, SSRN eLibrary (2008) (English).
- [16] Christopher C. Harmon, *Terrorism today*, 1 ed., Routledge, Oxford, UK, 2000.
- [17] Mark Harrison, *Counter-terrorism in a police state : The KGB and codename blaster, 1977*, The Warwick Economics Research Paper Series (TWERPS) 918, University of Warwick, Department of Economics, October 2009.
- [18] Bruce Hoffman, *Inside terrorism*, Columbia University Press, USA, 2006.
- [19] Woo-Sung Jung, Fengzhong Wang, and H. Eugene Stanley, *Gravity model in the korean highway*, *EPL (Europhysics Letters)* **81** (2008), no. 4, 48005.
- [20] David A. Lake, *Rational extremism: Understanding terrorism in the twenty-first century*, *Dialog-IO* (2002), 15–29.
- [21] William M. Landes, *An economic study of U. S. aircraft hijacking, 1961-1976*, *The Journal of Law and Economics* **21** (1978), no. 1, 1.
- [22] Dwight R. Lee, *Free riding and paid riding in the fight against terrorism*, *The American Economic Review* **78** (1988), no. 2, 22–26.
- [23] Roy H. Lindelauf, Peter E. Borm, and Herbert Hamers, *The Influence of Secrecy on the Communication Structure of Covert Networks*, *Social Networks* (2009).
- [24] Luis Lugo, *Mapping the global muslim population*, Pew Research Center, October 2009.
- [25] Eliza Manningham-Buller, *The international terrorist threat to the UK*, MI5 website (2006), <http://www.mi5.gov.uk/output/the-international-terrorist-threat-to-the-uk-1.html>.
- [26] Thierry Mayer and Soledad Zignago, *Notes on CEPII's distances measures*, <http://www.cepii.fr/anglaisgraph/bdd/distances.htm>, May 2006, Centre d'Etudes Prospective et d'Informations Internationales.

- [27] Edward F. Mickolus, *International Terrorism: Attributes of Terrorist Events (ITERATE)*, <http://www.icpsr.umich.edu/cocoon/ICPSR/STUDY/07947.xml>, 2009.
- [28] OECD, *Immigrants and expatriates: Total population by nationality and country of birth*, online, 2006, Organisation for Economic Co-Operation and Development.
- [29] Marc Sageman, *Leaderless jihad - terror networks in the twenty-first century*, University of Pennsylvania Press, Philadelphia, PA, 2008.
- [30] Todd Sandler, *Collective action and transnational terrorism*, *The World Economy* **26** (2003), no. 6, 779–802.
- [31] Todd Sandler and Walter Enders, *An economic perspective on transnational terrorism*, *European Journal of Political Economy* **20** (2004), no. 2, 301–316.
- [32] Jacob N. Shapiro and David A. Siegel, *Mathematical methods in counterterrorism*, ch. Underfunding in Terrorist Organizations, pp. 349–382, Springer-Verlag, 2009, Nasrullah Memon and Jonathan D. Farley and David L. Hicks and Torben Rosenorn, Eds.
- [33] ———, *Terrorist financing in comparative perspective*, ch. The Greedy Terrorist: A Rational Choice Perspective on Terrorist Organizations’ Inefficiencies and Vulnerabilities, Stanford University Press, California, 2009.
- [34] William F. Shughart, II, *Terrorism in rational choice perspective*, Working paper, 2009, Working Paper.
- [35] Alan Washburn and R. Kevin Wood, *Two-Person Zero-Sum Games for Network Interdiction*, *Operations Research* **43** (1995), no. 2, 243–251.
- [36] Richard Wike, *Pew global attitudes project*, Pew Research Center, 2006-9.
- [37] Gordon Woo, *Understanding terrorism risk*, [https://www.rmsweather.org/Publications/UnderstandTerRisk\\_Woo\\_RiskReport04.pdf](https://www.rmsweather.org/Publications/UnderstandTerRisk_Woo_RiskReport04.pdf), 2004, Report for Risk Management Solutions.
- [38] ———, *Mathematical methods in counterterrorism*, ch. Intelligence Constraints on Terrorist Network Plots, pp. 205–214, Springer-Verlag, 2009, Nasrullah Memon and Jonathan D. Farley and David L. Hicks and Torben Rosenorn, Eds.

## A Parameter Estimates

Tab. 1: Information about countries: the interception cost (left) and the yields from attacks (right). The interception cost ( $I_j$ ) is not known for all OECD states. For this reason, only the countries where it was available (the left table) were considered as possible targets.

Country	Intercept. Cost $I_j$
New Zealand	2.3
United Kingdom	2.1
Czech Republic	1.6
Hungary	1.6
United States	1.5
Slovakia	1.5
Estonia	1.5
Portugal	1.4
Italy	1.3
Spain	1.3
Poland	1.2
Netherlands	1.2
Israel	1.1
Belgium	1.1
Slovenia	1.0
Germany	1.0
Canada	0.9
Austria	0.9
Iceland	0.8
Ireland	0.8
Japan	0.8
Sweden	0.7
Finland	0.6
France	0.6
South Korea	0.6
Greece	0.5
Denmark	0.3
Luxembourg	0.2
Norway	0.2
Australia	0.0

Country	Yield $Y_j$
United States	-54.0
Japan	-24.1
Germany	-9.5
United Kingdom	-7.8
France	-6.8
Italy	-5.3
Canada	-3.8
Spain	-3.2
South Korea	-3.1
Australia	-2.2
Netherlands	-1.8
Sweden	-1.2
Belgium	-1.1
Austria	-0.9
Poland	-0.9
Norway	-0.8
Denmark	-0.7
Greece	-0.6
Finland	-0.6
Ireland	-0.5
Portugal	-0.4
Czech Republic	-0.2
New Zealand	-0.2
Hungary	-0.2
Slovakia	-0.0
Luxembourg	-0.0

Tab. 2: Translocation costs  $T_{ij}$  (country  $i$  to country  $j$ ) for select country pairs. Rows are countries of departure, columns are the destinations. Notice that Japan has relatively large barriers, as estimated by its abnormally low population of immigrants.

Destination →	Australia	Canada	France	Germany	Italy	Japan	South Korea	Spain	UK	US
Afghanistan	0.0	0.0	1.9	0.1	29.5	44.2	44.2	18.1	0.3	0.1
Algeria	0.2	0.1	0.1	9.9	15.1	32.4	32.4	9.2	6.2	1.9
Azerbaijan	0.6	0.3	10.3	4.3	50.2	71.6	71.6	9.3	5.1	0.2
Bangladesh	0.4	0.1	8.1	3.2	1.2	12.9	8.9	5.4	0.1	0.3
Burkina Faso	6.3	2.0	1.1	5.4	2.5	192.0	192.0	27.8	44.1	11.2
Chad	2.8	0.6	0.7	12.2	43.9	407.2	407.2	62.4	15.3	9.3
Cote d'Ivoire	2.1	0.5	0.1	2.8	0.8	17.7	17.7	8.1	1.5	1.2
Egypt	0.0	0.1	1.9	1.1	2.7	12.8	12.8	13.9	1.4	0.2
France	0.0	0.1	0.0	34.6	1.9	1.8	2.7	1.3	28.2	0.2
Guinea	2.2	0.4	0.3	0.4	3.4	4.8	4.8	0.6	8.3	1.2
India	0.2	0.1	4.9	3.5	5.9	64.4	153.1	9.4	0.3	0.2
Indonesia	0.3	0.2	2.5	0.9	7.6	5.0	3.2	7.0	1.3	0.3
Iran	0.0	0.0	1.2	0.5	4.4	3.1	3.1	4.0	0.5	0.1
Iraq	0.0	0.0	3.0	0.5	13.6	98.3	98.3	5.3	0.3	0.1
Jordan	0.0	0.0	3.5	1.4	2.9	9.2	9.2	1.2	0.8	0.0
Kazakhstan	0.5	0.1	7.4	23.1	5.9	81.6	81.6	8.8	2.9	0.4
Libya	0.0	0.1	6.3	4.3	0.8	55.4	55.4	15.1	0.7	0.4
Malaysia	0.0	0.0	0.8	0.1	4.1	1.8	14.8	3.7	0.0	0.1
Morocco	0.2	0.1	0.1	1.0	0.3	13.1	13.1	0.7	3.3	0.6
Mozambique	0.7	0.4	1.8	0.8	3.8	472.8	472.8	2.0	0.4	1.7
Nigeria	0.7	0.5	14.3	1.8	3.1	8.3	8.3	4.4	0.4	0.4
Pakistan	0.2	0.1	2.3	1.6	2.2	11.6	9.7	1.4	0.1	0.2
Palestine	0.0	0.0	2.7	1.5	15.5	1e+200	1e+200	3.9	0.7	0.0
Russia	0.1	0.1	6.8	38.3	6.8	10.3	10.3	3.1	7.5	0.2
Saudi Arabia	0.2	0.1	4.4	3.7	20.7	32.4	32.4	15.6	0.6	0.2
Senegal	0.4	0.4	0.0	1.3	0.1	6.3	6.3	0.4	4.7	0.8
Somalia	0.0	0.0	0.8	0.0	0.2	463.3	463.3	6.0	0.0	0.0
Sudan	0.1	0.1	7.9	2.8	23.6	34.5	34.5	34.5	0.8	0.5
Tajikistan	2.3	1.5	56.7	27.3	29.8	1967.0	1967.0	80.3	12.3	0.6
Tanzania	0.3	0.0	7.9	1.0	6.2	19.5	19.5	24.5	0.1	0.6
Tunisia	0.2	0.1	0.1	1.5	2.4	7.8	7.8	19.2	5.2	0.8
Turkey	0.0	0.2	0.4	0.1	24.4	10.8	10.8	38.2	1.1	0.3
UK	0.0	0.0	32.2	23.7	2.9	0.7	2.7	1.3	0.0	0.1
US	0.0	10.6	1.2	0.9	0.7	0.7	0.9	1.7	0.3	0.0

Tab. 3: The supply of plots for the default weight and change under two alternative weightings (high commitment and low commitment.) Certain countries are unusually dependent on the level of support the most radical segment provides, while others see relatively broad support for violence. Only the 30 largest sources are shown. For some countries in a particular region the sensitivity is identical because direct survey data was not always available. In those countries the radicalization values ( $\sigma^r, \sigma^s, \sigma^o$ ) were imputed from regional estimates.

Country	Supply $S_i$	High commitment	Low commitment
Indonesia	52745.4	-46.2%	24.6%
Nigeria	52687.8	-33.3%	17.8%
India	49624.7	-43.1%	23.0%
Bangladesh	39960.8	-33.8%	18.0%
Iran	26723.7	-30.6%	16.3%
Egypt	24731.6	-41.0%	21.8%
Pakistan	16537.8	-22.1%	11.8%
Algeria	12387.6	-30.6%	16.3%
Iraq	11021.7	-30.6%	16.3%
Sudan	10910.5	-30.6%	16.3%
Afghanistan	10168.3	-30.6%	16.3%
Saudi Arabia	9037.1	-30.6%	16.3%
Yemen	8462.6	-30.6%	16.3%
Ethiopia	8278.6	-39.7%	21.2%
Mali	8247.4	-23.2%	12.4%
Uzbekistan	8161.3	-43.1%	23.0%
Syria	7315.4	-30.6%	16.3%
Morocco	6878.5	-26.5%	14.1%
China	6680.7	-43.1%	23.0%
Niger	6497.3	-32.2%	17.2%
Malaysia	6466.6	-47.7%	25.4%
Turkey	5521.4	-44.0%	23.5%
Russian Federation	5081.9	-43.1%	23.0%
Palestine	4632.0	-21.1%	11.2%
Burkina Faso	4004.9	-32.2%	17.2%
Tunisia	3700.5	-30.6%	16.3%
Senegal	3668.5	-40.3%	21.5%
Guinea	3664.4	-32.2%	17.2%
Cote d'Ivoire	3338.1	-32.2%	17.2%
Somalia	3258.2	-30.6%	16.3%

In certain countries, such as Malaysia, Indonesia and Turkey support for violence is relatively broad. This can be seen from the large decrease in supply under the high-commitment scenario,  $(s_r, s_s, s_o) = (0.1, 0.2, 1.0)$ , compared to

the default weights  $(s_r, s_s, s_o)=(0.25, 0.50, 1.00)$ . In regions such as the Palestinian Territories, Pakistan and Morocco the support is more dependent on the radical minority, as seen from the relatively small increase under the scenario  $(s_r, s_s, s_o)=(0.33, 0.66, 1.00)$ . Overall, the 10 largest sources of plots are not more sensitive to those parameters than other sources.

## B Computation of Probabilities

In the framework of the theory of complex networks, attack plots could be represented as the motion of an adversary through a weighted network (the plot itself is the adversary we wish to stop.) The adversary aims to find an attack path or to hide, whichever plan has the lowest cost. To map such a decision to the framework of activity networks, connect the “attack” and “abandon” nodes in Fig. 2 to a node termed “end” with edges of cost 0. Thus, an attack on a country  $j$  corresponds to an adversary that starts at country  $i$  and goes through country  $j$  and then to the node “attack” and finally to “end”. The decision to abandon corresponds to an adversary that starts at country  $i$  then goes to “abandon” and then to “end”. The expected number of attacks on a particular target  $t$  can be computed by combining information about path costs with information about the supply of plots from a particular country  $S_i$  and the yield of abandonment  $A$ . Namely, it is the number of trips from all sources that arrive to the “attack” node from target country  $t$ .

The least-cost path corresponds to the optimal choice by the terrorists, but they can make mistakes. An attack plan under uncertainty could be described as a Markov chain [14, Ch. 3]. The chain has initial distribution proportional to  $S_i$ , and a transition probability matrix  $\mathbf{M}$  describing the likelihood of taking a particular edge on the network. The “end” node is the absorbing state of the chain. The  $\mathbf{M}$  matrix can be computed using the least-cost guided evader model described in [14, Ch. 3]. Briefly, for each edge  $(u, v)$  of the network, the transition probability through it is given by the formula  $M_{uv} \propto \exp(-\lambda(c(p_{uv}) - c(p_{u*})))$ , where  $c(p_{u*})$  is the cost of the least-cost path from node  $u$  to the end node, and  $c(p_{uv})$  is the cost of the path through edge  $(u, v)$ :  $p_{uv} = (u, v) \cup p_{v*}$ . Thus, the model generalizes the least-cost path model<sup>3</sup>. The parameter  $\lambda$  was set to 0.1, in the reported data, but its value has a smooth effect on the predictions of the model because of the smoothness of the exponential function. The number of plots against a target country  $t$  is now found by taking the probability of a trip to that target multiplied by the total number of plots  $(= \sum_i S_i)$ .

<sup>3</sup> To compute the distances to the “end” node,  $c(p_{uv})$ , we use the Bellman-Ford algorithm because edge weights are negative for some edges (e.g. yield from attacks). Ref. [14, Ch. 3] uses the faster algorithm of Dijkstra because it treats only the case of positive weights.